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Environmental Considerations for the Disposal of PBB-Contaminated Animals and Wastes

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Accidental contamination of livestock feed in 1973 by polybrominated biphenyls (PBB) led to the destruction of over 30,000 animals in Michigan. Animal carcasses of mostly dairy cattle along with some beef cattle, hogs, sheep and rabbits destroyed under the Federal Food and Drug Administration guidelines were disposed on the land at an environmentally safe site in Kalkaska County, Michigan. The geology and hydrology of the disposal site on state-owned land is considered favorable for the disposal of contaminated carcasses and to prevent any migration of PBBs into ground and surface waters of the area. Materials underneath the site are predominantly sand with layers of silts and clays of glacial origin. The vertical isolation from the surface to the water table is over 90 ft, and the horizontal isolation to the privately owned properties and surface water bodies is well over 1.5 mile in all directions. The site design provides necessary safeguards for minimizing surface water infiltration into disposal trenches and maximizing the protection to the environment. A series of water wells in the direction of flow are established for monitoring groundwater quality for years to come.

A 40-acre Gratiot County landfill located near St. Louis, Michigan, has received 269,000 lb of wastes containing 60 to 70% PBBs between 1971 and 1973. PBB wastes are intermixed with general refuse at various depths predominantly in the eastern half of the landfill. Phase I of the hydrogeological investigation shows that the landfill is situated immediately above the groundwater aquifer and a divide. Recently drilled test wells show traces of PBBs in the aquifer in all directions. Additional studies are planned in the near future for corrective measures and monitoring.

Introduction

This paper is divided into two parts in order to outline the environmental considerations given and precautions taken for the safe disposal of PBB-contaminated animal carcasses containing small quantity of PBBs in contrast to environmental problems created by the disposal of industrial wastes containing large quantity of PBBs in an improperly operated landfill. The first section deals with the animal disposal site located in Kalkaska County of Michigan and the second deals with the landfill site located in Gratiot County of Michigan (Fig. 1).

In the spring of 1974 the problem of disposing of contaminated carcasses in Michigan became critical. At that time the toxicity and other chemical and physical properties of PBBs were less known. Taking this fact into the consideration, the State of Michigan had decided to locate an environmentally safe site for the burial of carcasses. After reviewing several locations and existing landfills in Michigan, the site in Kalkaska County was chosen and test drilled in order to determine the long range protection to groundwaters of the area. The Gratiot County landfill near St. Louis became operational in late 1970, and it was designed only for the general municipal solid waste disposal. According to the Michigan Chemical Corporation report to the Federal Environment Protection Agency, PBB wastes in the landfill were disposed between 1971 and 1973. Wastes containing large amounts of PBBs (60 to 70%) were received in the landfill before any information about toxic effects of PBBs on animals were publically known. The Kalkaska animal disposal site contains approximately 100 lb of PBBs in all buried carcasses (D. R. Isleib, Michigan Department of Agriculture, personal communication). In view of the limited scope of this paper, some of the detailed and specific field and laboratory data is eliminated. Attempt is made to present broad facts

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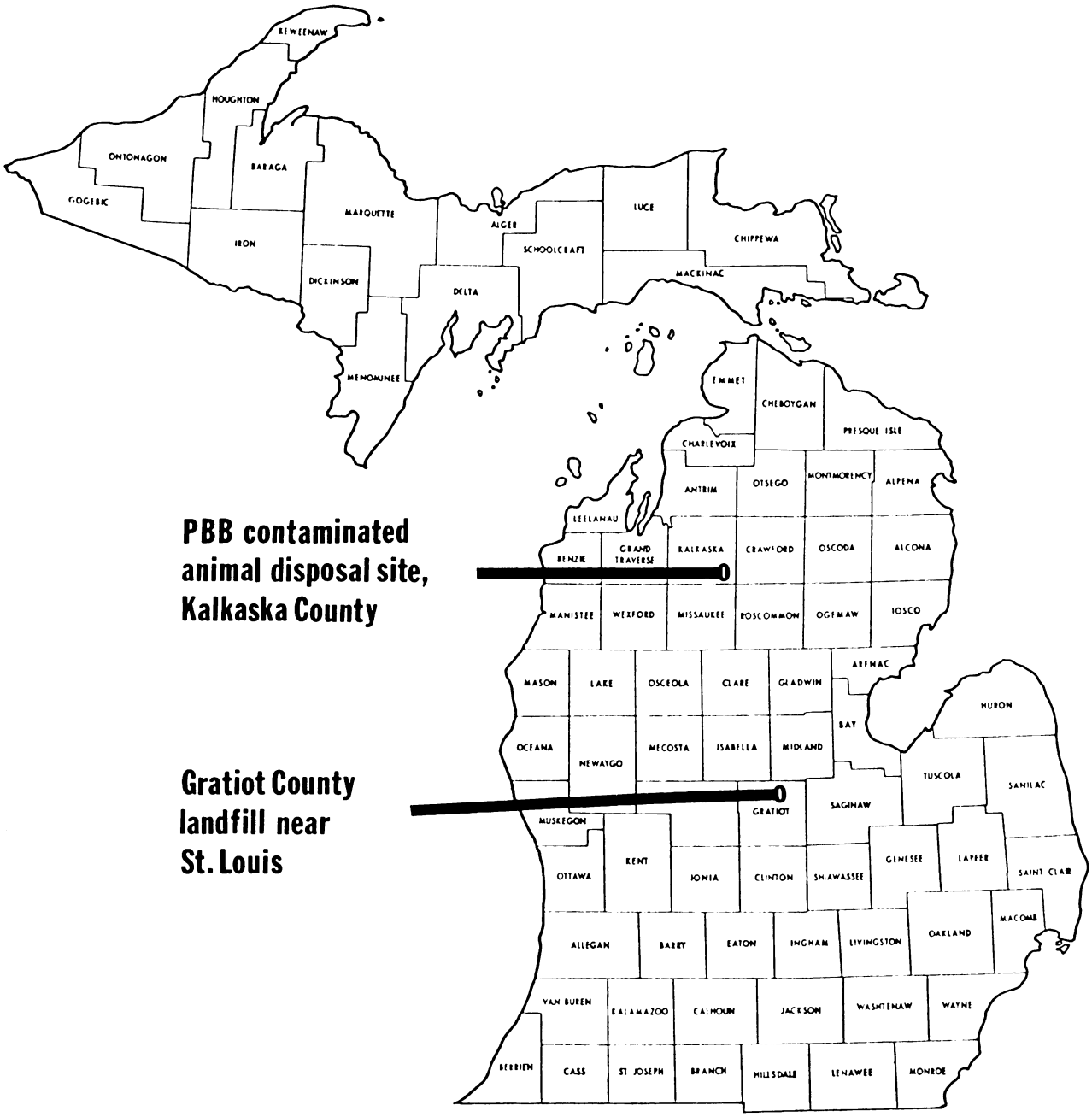

FIGURE 1. Location of disposal sites in Michigan.

to outline general considerations and concerns regarding the land disposal of PBBs in the environment.

PBB-Contaminated Animal Disposal Site

The 25-acre site is located on the state-owned land in E 1/2, SE 1/4, Section 10, T25N, R5W, Garfield Township, Kalkaska County, Michigan (Fig. 1). Prior to selecting the above location, preliminary factors such as geology, hydrology, topography, isolation from nearest inhabitants and surface water bodies, availability of access roads and natural openings, wildlife habitat, and forest management were considered. The site in Kalkaska County satisfied all above factors; further, a few test bores were obtained, and four groundwater observation

wells were installed at three locations (Figs. 2 and 3) for the accurate determination of subsurface geology and groundwater conditions.

Site Geology

The surface and near surface sediments in major parts of Michigan are of glacial origin and the site in Kalkaska County is placed in glacial sediments of the Late Wisconsinan age. The topography of the area is gently rolling with an average elevation of 1271 ft above the sea level at the site.

The subsurface test hole and well data show that the glacial sediments underneath and adjacent areas are predominantly sandy with some interbedded silts and clays (Fig. 2). Boring logs further indicate that at the depth of about 40 ft and deeper there is a minimum of 3 to 5 ft thick sandy silt and clay layer which continues throughout the disposal area. In some areas, traces of silt intermixed with sand are encountered below 40 ft and all the way down to the water table. Subsurface data from monitoring wells to the west and northwest indicate that silt and clay material slowly disappears in that direction.

Initially, observation wells were installed at three locations as shown in Figure 3 in order to determine the accurate depth of water table and the direction of groundwater flow. The static water levels in these wells indicate that water table is about 95 (±) ft below the ground surface and the direction of flow is N40°W with the rate of less than 1 ft/day. At location OB-C, an additional well into the deeper part of the aquifer was installed to observe if any vertical component of flow could be detected, but static water level data did not indicate any significant vertical component.

Additional installation of monitoring wells (indicated by triangle and letter M in Fig. 3) in the northwesterly direction have further confirmed the groundwater flow direction and provided with more subsurface information regarding the composition of glacial materials and aquifer thickness. Two

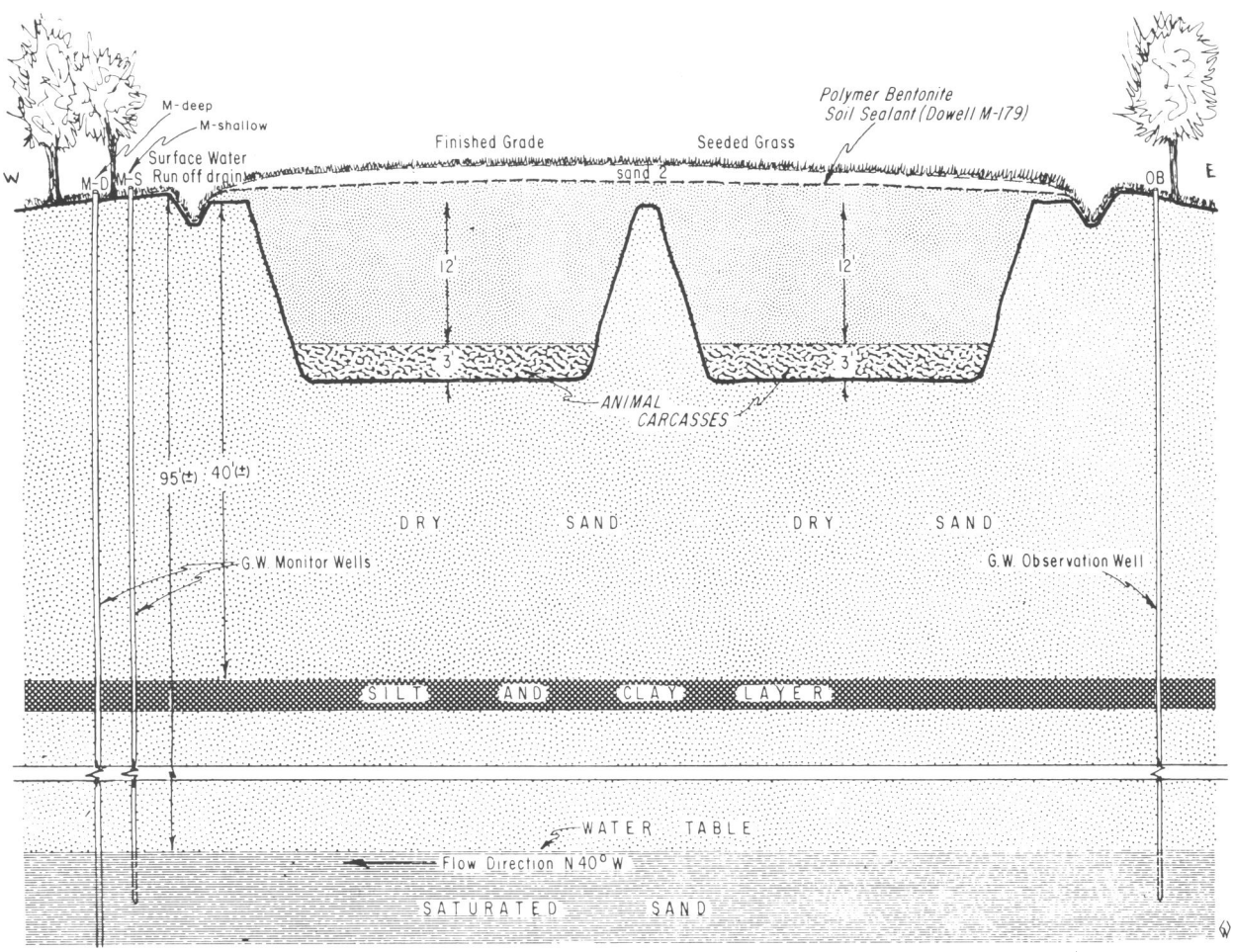

FIGURE 2. General east-west cross section through the PBB-contaminated animal disposal site, Kalkaska County Michigan.

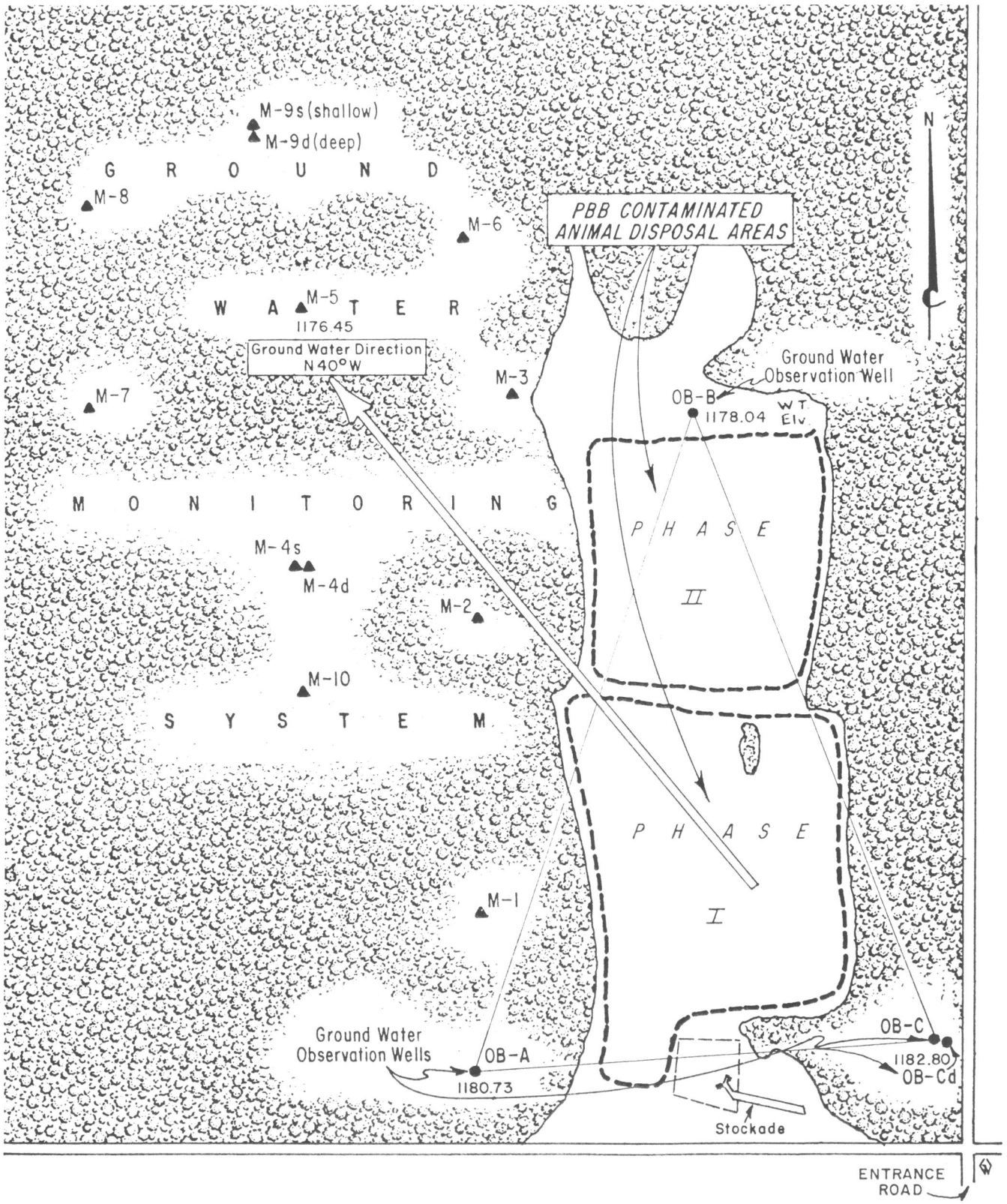

FIGURE 3. Map showing animal disposal areas and groundwater observation-monitoring well system, Kalkaska County, Michigan.

monitoring wells (M-4d and M-9d) extend to the depth of about 150 ft, indicating an aquifer thickness of at least 50 to 60 ft.

Method of Animal Disposal

In most cases, PBB-contaminated animals were brought alive to the site and then killed in a humane fashion in the stockade area (Fig. 3) under the supervision of veterinarians from the Michigan Department of Agriculture. Afterwards dead animal carcasses were deposited side by side to form one layer in a 15-ft-deep trench excavated in dry, sandy material as shown in Figure 2. Body cavities of animal carcasses were cut open for the escape of gases prior to placing 2 ft of sand immediately over them followed up by complete filling of trenches with at least 10 ft of sand within 24 to 48 hr.

After all trenches in designated disposal area (Figs. 2 and 3) were filled, the whole area was graded in order to provide adequate slopes for surface water runoff. Then the polymer bentonite soil sealant (Dowell M-179 product) was evenly spread at a rate of 35 tons per acre and blended in with 4 to 6 in. of sand. This seal was installed to prevent surface water infiltration into disposal trenches and provide increased runoff towards sealed drains along the perimeter of the disposal areas. Perimeter drains discharge surface water into shallow seepage basins located away from the disposal areas.

Further, on the top of the soil sealant layer, sand cover 2 ft thick was placed and the final surface was seeded with mixture of grasses in order to restore the landscape in its natural state which provides an excellent wildlife opening in a heavily forested area. Rainfall in this part of the state averages 32 in. per year. It is estimated that two thirds of the rainwater is lost in the form of evapotranspiration and one third of the rainwater is partly lost as runoff from the site above soil sealant layer and partly absorbed by the root system developed by the vegetation, thus reducing infiltration potential into carcasses containing PBBs and increasing protection to the groundwaters of the area.

As shown in Figure 3, the Phase I disposal area first received approximately 10,000 to 11,000 animal carcasses, most of which had PBB levels above 1 ppm in fat. The Phase II disposal area received close to 20,000 animal carcasses, mostly having PBB levels above 0.3 ppm but in general less than 1 ppm in fat. The Phase I area appears to be larger than Phase II but it received almost half the number of animals received by Phase II area. This happened because in the initial stages of disposal operation lot of space between trenches was not utilized due to lack of proper planning of trench locations, but the trench depths were still maintained at 15 ft below ground level.

Groundwater Monitoring

In addition to initially installed four observation wells, 12 more wells have been carefully installed in the direction of groundwater flow, as shown in Figure 3, to provide a complete groundwater monitoring system. This system will be used to monitor water table fluctuations and quality of groundwater. Out of a total of 16, wells M-4d and M-9d provide monitoring points 45 to 55 ft below the water table.

Monitoring data so far collected since 1974 show that water table elevation in this area fluctuates up to 1 ft, and there has been no degradation in groundwater quality from PBBs or any other contaminants from the disposal area.

Gratiot County Landfill and PBB Wastes

The 40-acre landfill is located in SW 1/4, SE 1/4, Section 30, T12N, R2W, Bethany Township, Gratiot County, Michigan (Fig. 1). The landfill is owned by the County and is situated southeast of the City of St. Louis (Fig. 4). For last seven years it has provided a large solid waste disposal facility in the area.

After learning about the presence of 269,000 lb of waste containing 161,400 to 188,300 lb (60 to 70%) of polybrominated biphenyls in the landfill, in March of 1977 the Michigan Department of Natural Resources started preliminary (Phase I) hydrogeological investigation of the site. The investigation was conducted for locating PBB wastes in the landfill and determining possible contamination of the ground and surface waters of the area. The Phase I study was completed in July of 1977 and the information presented in this paper pertains to that phase of hydrogeological work. Presently the monitoring of water quality continues and further in-depth hydrogeological (Phase II) investigation is being planned. The Phase II study will hopefully establish elaborate monitoring system and provide recommendations for final corrective measures.

Area Geology

The landfill is located on a rather narrow northwest-southeast trending (Fig. 4) Gladwin recessional moraine of the Saginaw ice lobe of the Middle Wisconsinan age. The thickness of the glacial drift in the site area is approximately 400 ft underlain by

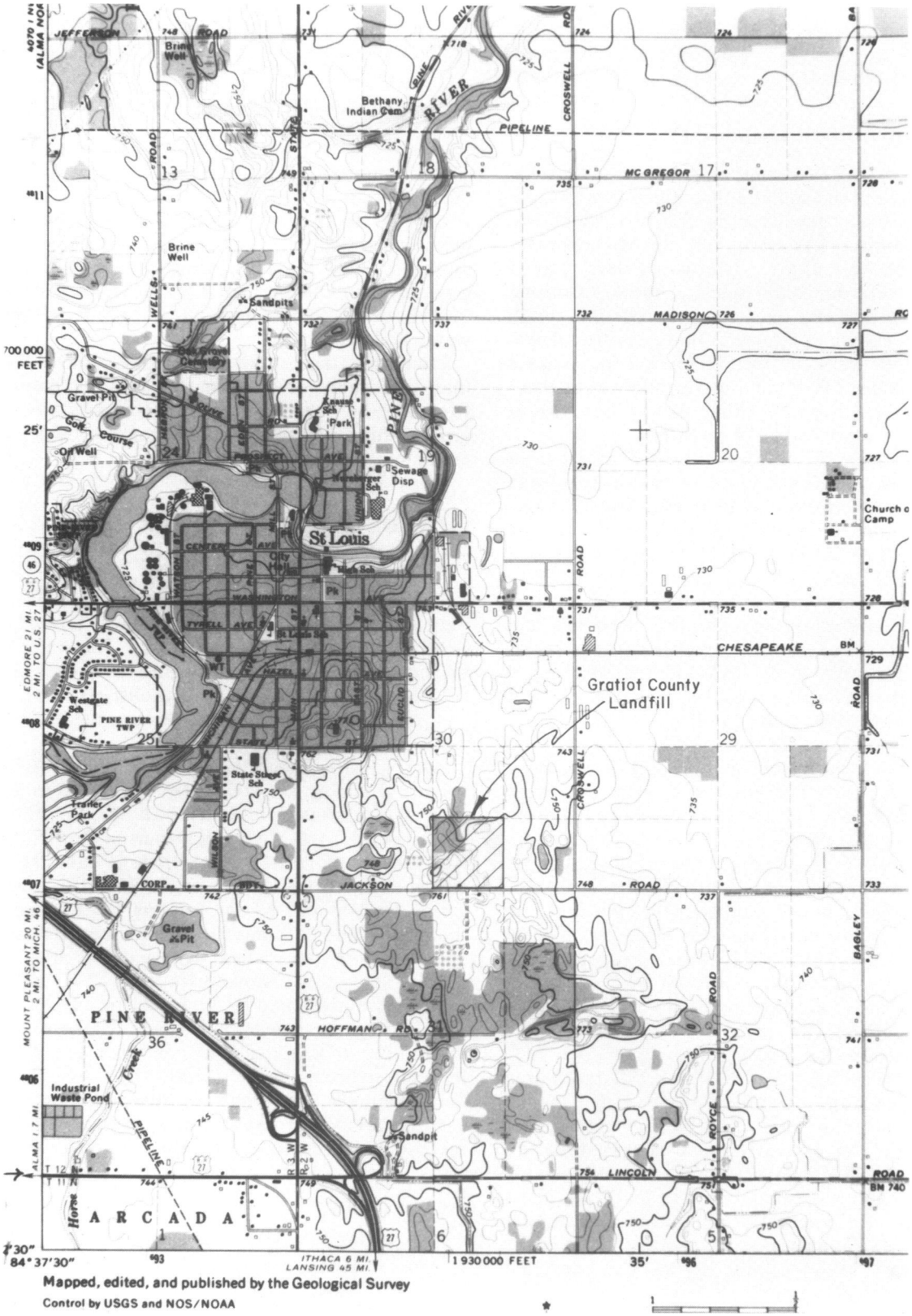

FIGURE 4. Location of a 40-acre Gratiot County landfill in relation to the area topography and the city of St. Louis (1).

sandstone and shale bedrock which is a part of the Grand River formation of Late Pennsylvanian Period. Well records in the area indicate that upper part of the glacial drift is composed predominantly of clay and silt tills which are interbedded with stratified and sorted sand and gravel deposits. Farther to the east and northeast of the site, the glacial drift changes from morainal deposits to lake bed deposits which also consist of clay, silt, and sand. Most water supplies in the area are obtained from permeable sand and gravel aquifers within the drift and in some cases from the sandstone bedrock.

Area topography varies from gently rolling hills to gradually sloping ground. The landfill is also located on a surface water drainage divide which is a part of the Pine River subbasin of the Saginaw River drainage basin.

Method of Investigation

In 1970, the 40-acre landfill site was tested with nine shallow soil borings shown in Figure 5. Based on that information, recent Phase I hydrogeological investigation was planned which consisted of 31 test borings ranging in depth from 11 to 53 ft. In addition, 11 groundwater observation wells were installed in shallow aquifer outside the landfill boundaries and three more wells were installed inside the landfill within the refuse mass containing PBB wastes. Well depths ranged from 18 to 41 ft below ground. Soil and refuse samples were taken at every 5 ft interval and/or change in formation.

Test borings in the landfill area (Fig. 5) were specifically designed to sample earlier deposited PBB contaminated wastes and did not extend below the bottom of the refuse mass. Test borings outside the landfill area were drilled to delineate any groundwater aquifers within 50 ft of the glacial drift and to reveal further information regarding the hydrogeological setting of the area. Groundwater observation wells provided the information regarding the aquifer conditions and water level elevations.

Refuse samples within the landfill were analyzed for the presence of PBBs. At the same time liquids

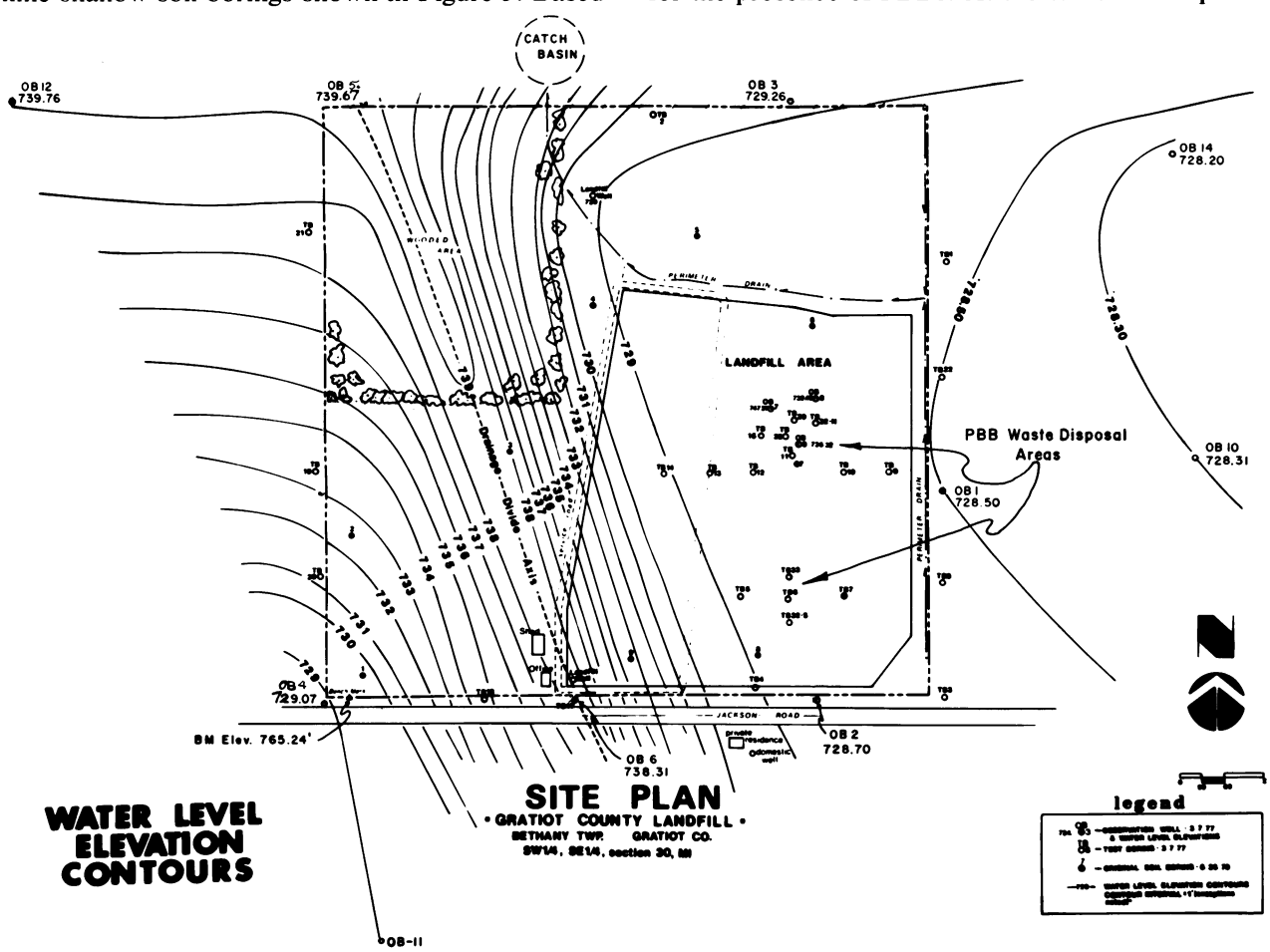

FIGURE 5. Site plan of Gratiot County landfill showing fill boundaries, test borings, observation well locations, and water level elevation contours.

collected from the landfill wells and one test hole were analyzed for the PBB content. Also, periodically groundwater samples from 11 wells outside the landfill boundaries were sampled for PBB content. All groundwater samples and leachate samples were also analyzed for other chemical parameters; such as COD, TDS, Cl, Fe, SO_4, phenols, and several heavy metals. Domestic well waters in the vicinity area were sampled by the local health authorities for possible PBB content.

Surface water and sediment samples were taken from perimeter drain to the east and northeast side of the landfill and catch basin area to the north. Those were also analyzed for the PBB content.

Summary of Major Findings

Geology and hydrology of the area is very complex. Vertical and lateral extent of subsurface formations are unpredictable. A shallow usable aquifer exists beneath the landfill and extends into the neighboring areas. Vicinity water well records indicate that a number of shallow wells are completed in this shallow aquifer. Well records also indicate extensive use of deeper aquifers in this area.

The landfill site is located on the groundwater divide as shown in Figure 5. Hydraulic conductivity of aquifer sands, groundwater gradient, and rate of flow varies in diffferent parts of the landfill and adjoining areas.

In the central eastern portion of the landfill, refuse was deposited in a previously existing valley (Fig. 6). In some areas of the valley, natural clay seal at the base of the fill has been removed by excavation prior to landfilling which provides direct connection between the refuse and the groundwater aquifer. In the same area of the landfill test boring samples and observation wells (OB-7, OB-8 and OB-9) indicate saturation of refuse mass due to heavy infiltration and as a result leachate-groundwater mounding has been developed. This mound appears to have hydraulic connection with the shallow groundwater aquifer.

Test borings indicate in general the existence of a clay layer in variable thickness above the aquifer. Also, some of the deep borings indicate the existence of a clay till layer beneath the aquifer (Fig. 6), but the horizontal extent and thickness of both clay layers and also sand and gravel aquifer is unpredictable and not well known at this time.

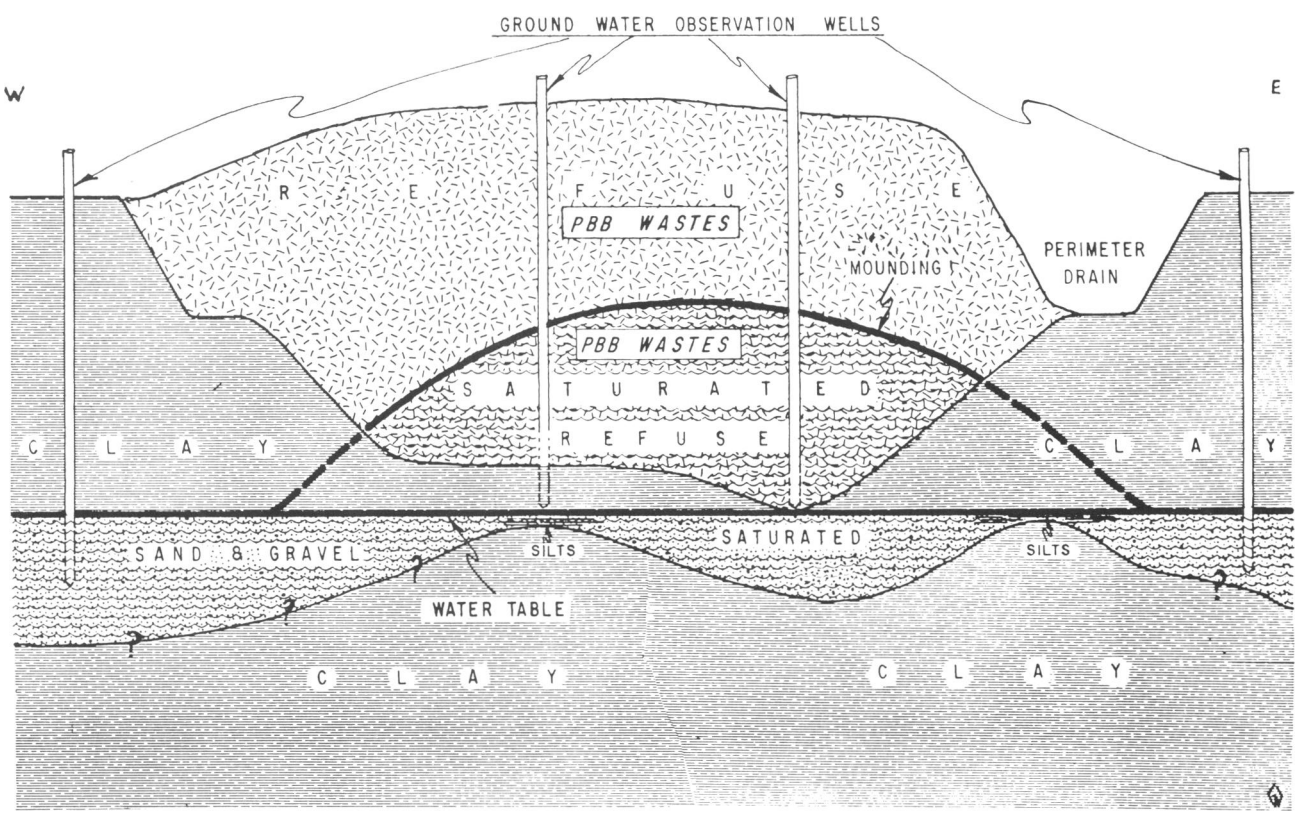

FIGURE 6. General east-west cross section through the central eastern half of the Gratiot County landfill.

As shown in Figure 5, two areas have been located containing PBB waste at various depths. Test samples show that, in general, the concentrations of PBBs in the fill increase with depth and are highest between 10 and 25 ft below the top of the refuse. At depth greater than 25 ft, PBB concentrations seem to decrease. Refuse is encountered up to depth of 40 ft in the area of observation wells 7, 8, and 9.

Groundwater samples from 11 observation wells outside the landfill area have shown one time or another trace levels of PBBs ranging from 0.1 ppb to 4.4 ppb, whereas, the contaminated water samples taken from 3 wells and 1 test boring inside the refuse mass have shown levels of PBBs ranging from 0.5 ppb to 26 ppb. Results are reported in Table 1. The presence of PBBs in observation wells to the west side of the groundwater divide cannot be explained at the present time, and it warrants further testing in the fill area to the west side of the landfill.

Table 1. PBB levels in groundwater observation wells around and inside the Gratiot County landfill.

	PBB level, ppb			
Well number[a]	3/28/77	5/13/77	6/8/77	7/28/77
Outside the landfill				
OB-1	<0.1	no sample	0.1	0.1
OB-2	0.3	"	0.1	0.8
OB-3	0.3	"	<0.1	<0.1
OB-4	0.3	"	0.5	<0.1
OB-5	0.3	"	<0.1	<0.1
OB-6	0.6	"	1.0	1.2
OB-10	no sample	0.5	<0.1	<0.1
OB-11	"	4.4	<0.1	4.0
OB-12	"	<0.1	<0.1	0.5
OB-13	"	0.3	0.3	0.5
OB-14	"	1.9	0.1	1.5
Inside the landfill				
OB-7	2.2	no sample	2.2	2.3
OB-8	0.5	"	no sample	no sample
OB-9	13.0	"	0.4	0.4
TB-29 (test boring)	26.0	"	no sample	no sample

[a] Refer to Figure 5 for locations of wells and test boring.

Groundwater samples from wells, specifically to the north and northeast side of the landfill, show very high levels of other contaminants migrating off the site. Due to the limited scope of this paper, results are not reported here.

Various PBB concentrations ranging from 0.1 ppb to 17,000 ppb have been detected in surface water and sediment samples taken from the surface drain to the east and northeast part of the landfill and in the catch basin area north of the landfill on the private property. This may be occurring due to the migration of leachate generated in the PBB waste containing refuse into the existing surface water drain through the landfill, which also empties into the catch basin area to the north.

Domestic drinking water wells so far do not show any traces of polybrominated biphenyls.

Conclusions

The site geology, method of animal disposal, site design, and groundwater monitoring program provide assurance for the long-range protection of the environment from the PBB contamination. The site will not leave any adverse impact on the land use for hunting and forest management. Further, PBBs in carcasses buried 15 ft below the ground should not move very far in the soil or leach to the groundwater aquifer, thus providing permanent protection to the human and animal health. Earlier PBB and soil adsorption studies in 1974 using soil samples from the Kalkaska County site (D. R. Isleib, L. W. Jacobs, and B. P. Shah, unpublished data) and also studies by Jacobs et al. (*2*) indicate that PBBs may remain in the soils for many years because of their resistance to degradation.

Earlier operational methods have created serious environmental problems at the Gratiot County landfill. These problems are further compounded by large volumes of PBB wastes which are deposited in a hydrogeologically delicate area of the landfill. Even though trace levels of PBBs are detected in the groundwater aquifer only in the adjoining areas of the landfill, long-range leaching and their possible extent of migration are not very well understood at this time. Recent investigation revealed some of the geological and hydrological complexities of the area, but more data are needed to draw final conclusions, and corrective action is required to restrict further release of PBBs and other contaminants in the environment. Hopefully, additionally planned hydrogeological studies will provide much needed information and an adequate monitoring system.

Finally, considerations must be given to hydrogeology and design of land disposal site prior to disposal of toxic and hazardous materials such as polybrominated biphenyls.

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